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Power Increase in the STAR-LM Generation IV HLMC Reactor*

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The Secure Transportable Autonomous Reactor-Liquid Metal (STAR-LM) is a 300 to 400 MWt class modular, factory-fabricated, overland transportable, autonomous/load following, proliferation resistant, passively safe reactor concept that takes advantage of the intrinsic benefits of a fast neutron spectrum core utilizing high thermal conductivity nitride fuel and 100% + natural circulation heat transport using lead-bismuth eutectic (LBE) heavy liquid metal coolant (HLMC).[1-5] STAR-LM has the potential to meet all of the U.S. Department of Energy Generation IV goals of sustainable energy development, safety and reliability, as well as economics.

The STAR-LM concept was originally developed for a nominal operating power level of 300 MWt. However, upon further investigation, it has been determined that the original concept is sufficiently robust to enable a significant increase in the power level to 400 MWt without enlarging the size of the nuclear steam supply system (NSSS) of which major components reside inside the coolant module vessel containing the LBE primary coolant. The system layout of the NSSS is the same as that presented previously and is illustrated in Figure 1.

Table 1 compares typical design and nominal operating conditions for thermal power levels of 300 and 400 MW. The same core diameter and active height have been retained. However, the fuel rod diameter and fuel rod triangular pitch-to diameter ratio have been increased while maintaining the same cladding-fuel LBE bond gap thickness thereby increasing the fuel mass. This maintains the limitation on fuel specific power.

To facilitate purely natural circulation heat transport and heat removal at the higher power level, the vertical height difference between the center elevations of the steam generator (SG) tubes and the active core has been increased together with the (SG) tube height. The components still fit comfortably inside the coolant module vessel which does not exceed the restrictions (19m height; 6.1m width) for overland (rail) transportability from the factory to the site.[6]

The secondary side working pressure has been raised to promote greater efficiency. The SG tube inner diameter has been increased and the tube pitch-to-outer diameter ratio decreasd to tend to reduce LBE frictional losses inside the taller SG tubes. The SG tube wall thickness has been increased to 3 mm to resist the effects of corrosion on both sides fo the tube wall. Figure 2 shows the calculated dependency of the peak cladding inner surface temperature upon the SG tube inner diameter for different tube P/D ratios. It is observed that increasing the SG tube inner diameter to 1.8 centimeters and reducing the pitch-to-diameter ratio to 1.2 significantly reduces the peak cladding temperature.

Although the greater steam generator pressure requires a higher core inlet temperature limited from below by the feedwater temperature, the calculated peak cladding temperature of 580 degrees Centigrade remains low enough for the utilization of HT9 or advanced ferritic steels as structural materials.

In summary, the STAR-LM concept is robust with respect to an increase in power from the original 300 MWt level to 400 MWt. Further power increases are still feasible with additional optimization.

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Table 1. Comparison of 300 and 400 MWt STAR-LM Design and Operating Conditions

Core Thermal Power	300	400
Core Diameter, m	2.5	2.5
Core Active (Heated) Zone Height, m	2.0	2.0
Fission Gas Plenum Height, m	0.5	0.5
Fuel Rod Cladding Outer Diameter, m	1.27	1.91
Fuel Rod Triangular Pitch-to-Diameter Ratio	1.48	1.50
Core Hydraulic Diameter, m	1.78	2.82
UN Fuel Smeared Density	0.66	0.78
Core Fuel Mass, Kg	27500	35300
Steam Pressure, MPa	7.0	10
Saturation Temperature, C	286	311
Feedwater Subrooling, C	20	20
Height Difference Between SG and Core Thermal Centers, m	6.25	9.0
Steam Generator Tube Height, m	3.0	4.0
SG Tube Inner Diameter, m	1.27	1.80
SG Tube Thickness, mm	2	3
SG Tube Triangular Pitch-to Diameter Ratio	1.35	1.20
Core Inlet Temperature, C	291	320
Core Outlet Temperature, C	474	489
Mean Temperature Rise Across Core, C	185	169
Peak Cladding Outer Surface Temperature, C	506	558
Peak Cladding Inner Surface Temperature, C	516	580
Steam Superheat, C	61	82
Coolant Velocity in Core, m/s	0.38	0.54

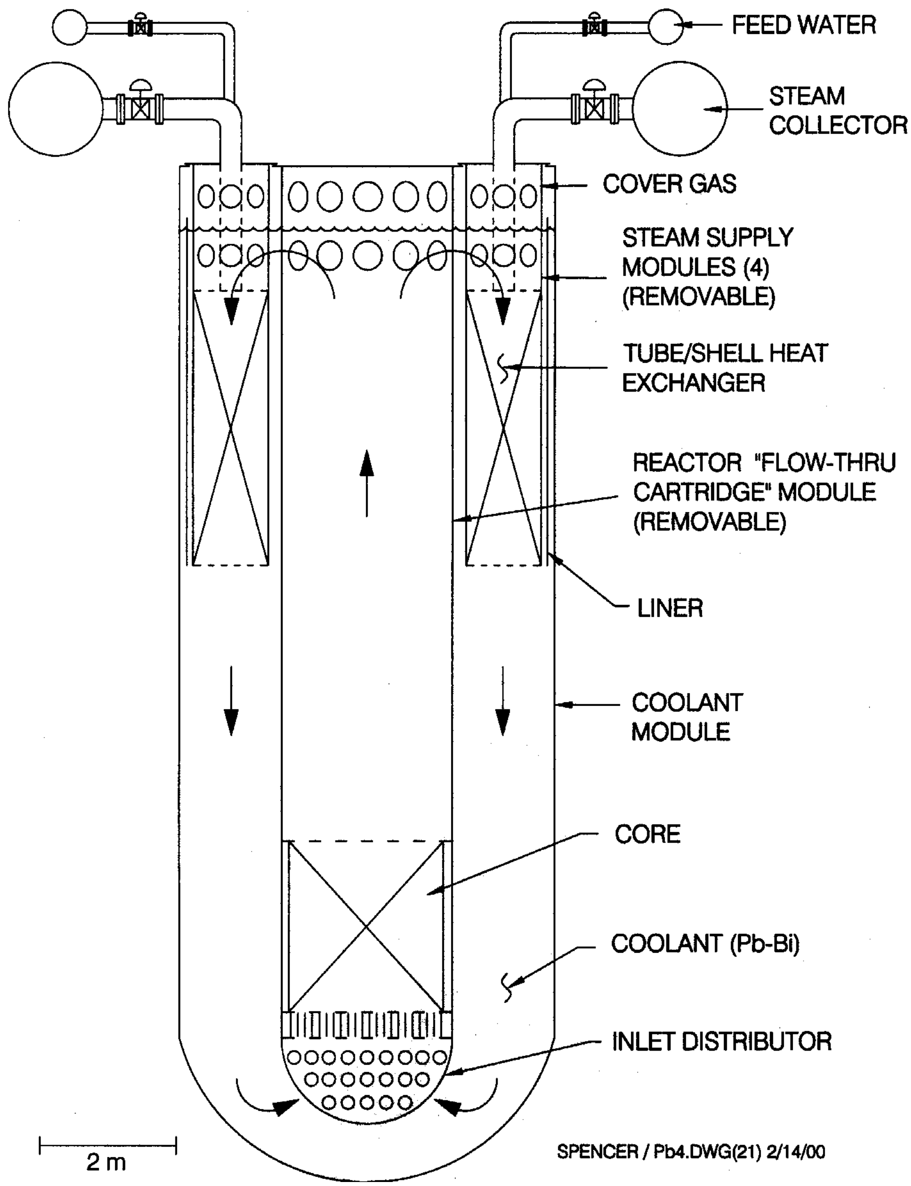

Figure 1. STAR-LM Concept for Modular, Simplified 300 to 400 MWt Reactor with Flow-thru Fuel Cartridge, 100% Natural Circulation, and In-vessel Steam Generators.

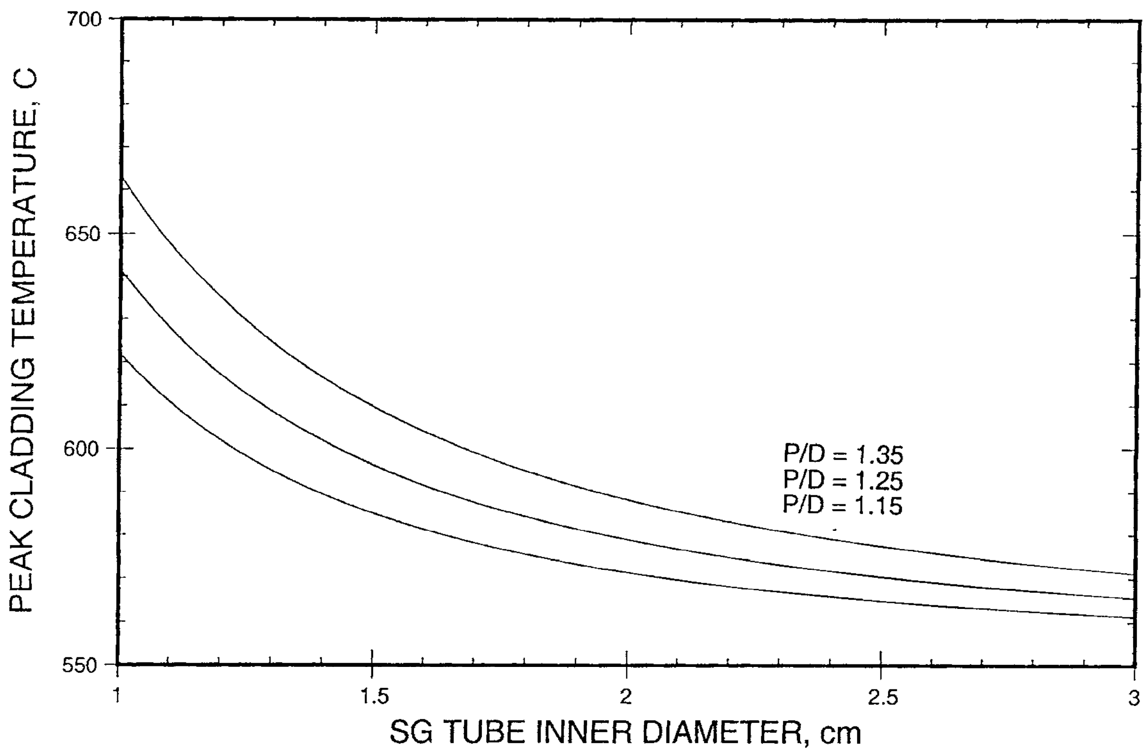

Figure 2. Effects of Steam Generator Tube Inner Diameter and Triangular Pitch-to-Diameter Ratio Upon Peak Cladding Temperature for 400 Mwt Core Power.